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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Plain or Sleeve Type Bearings

A discussion of those factors which affect Lubrication covering Bearing Metals, Oil Grooving and Methods of Lubrication

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Maintenance of Lubrication

THE sleeve type bearing is a most necessary factor in the construction and operation of industrial, power plant and automotive machinery. In fact, for the carrying of such rotating elements as the shafting of the steam turbine, the eccentrics and pins in certain marine or stationary steam engines and the crank connections of a Diesel engine, the sleeve type bearing can probably never be supplanted by any more efficient design.

In addition to being a supporting medium for shafting, pins or journals, the sleeve type bearing functions as a reducer of friction. But it cannot function alone in this regard. Lubrication or the development of an adequate film of lubricating fluid within the clearance space must be continually maintained.

Maintenance of such a lubricating film requires (a) continuous delivery of the necessary amount of lubricant to furnish the film, and (b) suitable bearing construction to permit of even spreading throughout the clearance space.

In consequence, we present the accompanying article for the purpose of clarifying this broad topic of Sleeve-type Bearing Lubrication. It should be of decided interest to the operating engineer, the machine designer and the student, for hand-in-hand with judicious selection of suitable lubricants, and employment of proper means of application, will go correct bearing construction from metals refined to meet bearing temperature and pressure conditions.

We welcome your inquiries as to the proper grade of Texaco Lubricant to use under any condition, and we offer Texaco Lubricating Engineering Service as an aid wherever difficulty may arise.

THE TEXAS COMPANY

Texaco Petroleum Products

Dept. H, 17 Battery Place, New York City

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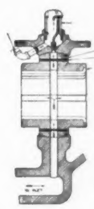
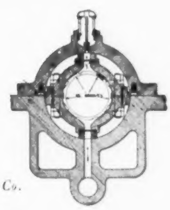
Plain or Sleeve Type Bearings



Courtesy of Allis-Chalmers Mfg. Co.



A discussion of those factors which affect Lubrication covering Bearing Metals, Oil Grooving and Methods of Lubrication

ATTAINMENT of effective lubrication of a plain or sleeve type bearing is normally dependent upon three factors, viz.:

The design and construction of the bearing,

The efficiency of the means of lubrication, and

The suitability of the lubricant.

As a general rule each will be more or less contingent upon the others. Grease, for example, cannot be used in a ring oiled bearing; nor can oil be used in a compression grease cup. These are typical of conditions, of course, which are virtually obvious and usually readily realized. And yet they may be frequently over-shadowed by operating details of seemingly far more consequence, to perhaps result in the ultimate detriment of the bearings involved, and increase in costs of upkeep and repair.

To the marine engineer, especially, who may be called upon to renew bearings under difficult working conditions, all this will be appreciated. At sea he will not always have a machine shop to depend upon, nor can he call in the representative of a bearing manufacturer to aid in determining why a bearing has "gone wrong." He must develop this himself, and furthermore take steps to insure that past faults will be corrected in the new bearing.

His interest in bearings and bearing metals should, therefore, be acute. Such interest should likewise be developed by every stationary or industrial operator who may have to deal with equipment involving bearings of the above type. More intimate familiarity with the details as discussed hereafter will undoubtedly lead to better machine performance, more intelligent lubrication and decrease in maintenance costs.

Pouring and Casting of Bearing Metals

From a constructional point of view, the sleeve type or so-called plain bearing, broadly involves consideration of bearing metals, methods of formation, and provisions for oil film maintenance in the form of suitable grooves and proper beveling or chamfering of breaks in the bearing surface.

The extent to which a bearing can be expected to function effectively will depend upon its initial formation, viz.: the manner in which it has been poured or cast, the temperature of pouring and the precautions observed in preheating the mould or bearing shell.

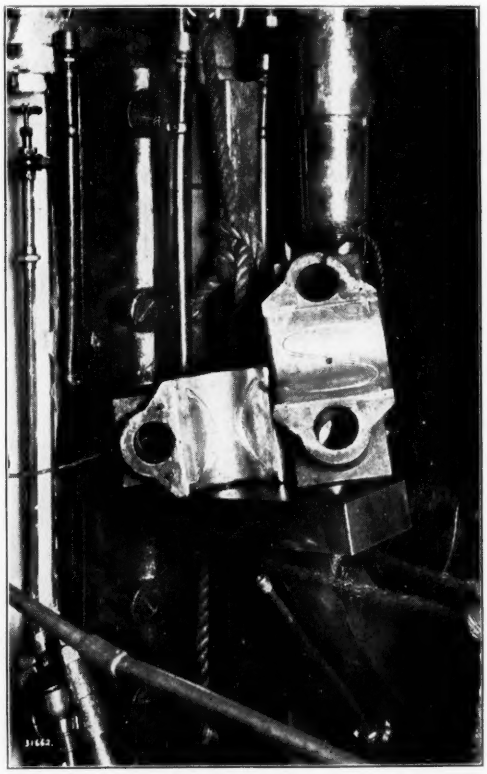
The temperatures involved will, in turn, be contingent upon the type of bearing metal used, its base and the relative percentages of copper or antimony for example, which are contained. The average temperature of pouring will range from 600 degrees F. to 900 degrees F. It is evident, therefore, that every care must be taken to proceed in accordance with the manufacturer's specifications in this connection. Some very helpful data is available in this regard. In part it is reproduced herewith as a matter of general interest.

MELTING THE METAL

The first step in bearing manufacture is to melt the metal. This should be done in a clean ladle, heating to pouring temperature as quickly and as uniformly possible. The metal should then be cast at once. Powdered rosin should be used both as a flux and to prevent spattering of metal in pouring should there be any moisture left in the shell, or should the latter be perhaps too cold. It is often injurious to overheat bearing metal, or to prolong the heating, due to possibility of oxidation and alteration of the alloy. The proper pouring temperatures of some of the different grades of Hoyt metals, for example, are shown in the following table.

Brand of Hoyt Metal	Melting Point	Liquidation	Proper Pouring Temp.
Oil Engine	462° F.	791.6° F.	916° F.
Electric Railway	460° F.	783° F.	908° F.
Genuine "A"	437° F.	699.8° F.	824° F.
Trojan	368.6° F.	539.6° F.	700° F.
Faultless A	364° F.	558° F.	683° F.
Standard No. 4	476.8° F.	509° F.	634° F.
Gas Engine	464.0° F.	500° F.	625° F.
Eagle "A"	469.4° F.	500° F.	625° F.

The melting point and copper content of a bearing metal will have a decided influence upon its proper pouring temperature. As a rule the higher the copper content the higher the pouring temperature should be. Furthermore, due to the fact that copper has a tendency to segregate, a thorough stirring and skimming of dross prior to pouring is advisable. Stirring with an upward motion will effectively prevent development of unmixed strata or layers of the ingredients in any bearing metal,



Courtesy of The Texas Company, Marine Dept.

Fig. 1—Typical marine engine bearing construction. Top and bottom crosshead pin bearings from S. S. Lightburne. Note top bearing to right with single oil hole and S-shaped groove. Bottom half is set at left. Change of direction of pressure on such bearings requires grooving of both bearings, the half-moon idea being employed on the bottom half.

especially at the bottom of the container. Due to difference and specific gravity, this possibility must be carefully guarded against, for it may readily occur if a molten alloy is allowed to remain at rest for any length of time.

Should bearings be poured from stratified metal subsequent trouble in service will be very apt to occur, for the base metal, be it tin or lead, will have no particular sustaining ability. With lead base metals especially, the lower part of a bearing poured from improperly mixed babbitt may be soft and tend to squash out. In turn the presence of an excess of perhaps a harder or more brittle metal such as antimony on the wearing surface may lead to scoring of the journal, overheating or cracking.

If bearing metals are underheated, coarse granular castings may result. On the other hand, if overheated, partial oxidation of certain of the constituents may occur, with shrinkage,

or perhaps softening, together with the development of impaired bearing ability. A dirty appearance will often indicate overheating.

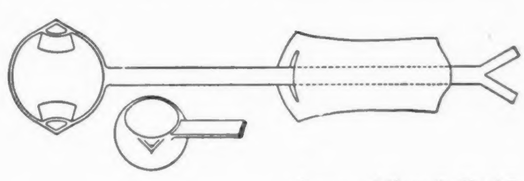
Of course, the most satisfactory way to regulate temperatures prior to pouring is to use a pyrometer and follow closely the pouring instructions and temperatures as advised by the bearing metal manufacturer. On the other hand, very often a pyrometer will be lacking. Where such is the case, it has been developed with lead base metals that a reliable method of ascertaining when the metal is right for pouring is to use a white pine stick for stirring. When it chars the pouring temperature has about been reached. Where tin base metals or alloys containing upward of 3% of copper having an approximate liquidation point of 650 degrees F. are involved, however, actual ignition of the stirring stick must occur before the metal is about ready to pour.

PREHEATING OF BEARING PARTS

While heating the bearing metal it is also important to clean and preheat the bearing parts, such as the mould or shell. This will burn off any grease or moisture, to insure complete contact, and equal shrinkage of both bearing and shell as cooling occurs. Were molten metal to be poured into a cold shell blow holes might occur due to gas pockets, and premature shrinkage might lead to incomplete filling of the mould, with poor formation of the bearing. In subsequent operation, such a bearing might be torn loose, or develop flaking when subject to the turning force of the rotating shaft or journal.

The extent to which this might occur would depend upon the degree of lubrication maintained. A relatively poor bearing may give excellent service if effectively lubricated. Yet, any impairment of oil flow due to clogged oil grooves for example, may lead to decidedly serious consequences if the bearing has not been properly poured in the first place.

To obviate any possibility of the above it is, therefore, important to preheat the shell and



Courtesy of Magnolia Metal Co.

Fig. 2—Ladles of the self-skimming type. By use of bridge device shown the size of metal stream can be predetermined. Splashing and passage of slag to mould are prevented by use of such a bridge. Note the leather hand protector on the handle.

journal or mandrel, wherever practicable, prior to pouring of the bearing. More even cooling and shrinking with smoother flow of metal will result, and settlement or stratification of heavier ingredients in the mould will be more nearly prevented.

The following temperature limits for preheating of shells and mandrels are quoted from the Magnolia Metal Bearing Book, viz.:

Bronze shells, solid, tinned	100 to 125° cent. (212 to 255° Fahr.)
" " split "	125 to 150° cent. (255 to 300° Fahr.)
Iron " " or solid	220 to 260° cent. (430 to 500° Fahr.)
Steel " " " "	220 to 260° cent. (430 to 500° Fahr.)
Iron or steel shells, tinned	200 to 250° cent. (390 to 480° Fahr.)
Mandrels	125 to 150° cent. (255 to 300° Fahr.)

"Iron or steel shells may be considered sufficiently heated when a stick of '50-50' solder touched to the surface will just melt.

"The mandrel is at the right temperature when water evaporates rapidly from the surface without spluttering."

TREATMENT OF SHELLS

In this regard, E. L. Post & Co. suggest that bronze shells be cleaned with muriatic acid and tinned with pure block tin, if possible, as solder is not always reliable unless it is known to be half and half (tin and lead). After tinning, bearings should be heated to a point where tinning shows signs of sweating.

With steel castings it is advisable to machine the surfaces, and also tin the same, before pouring the metal.

On cast iron or malleable shells, good anchorage is necessary and tinning is not recommended. After pouring the metal, however, it should be hammered or peined, a good riser being left on each bearing to take care of compression in peining or shrinkage. Borings can be used again, provided they are kept free of foreign matter such as steel filings, etc., by using a piece of canvas or mesh screen to catch them.

POURING BEARING METALS

With bearing shell and mandrel heated to the proper degree and the bearing metal melted to pouring temperature, the next step is to pour or cast the actual bearing. The Magnolia Metal Bearing Book goes into detail in this regard. It states that

> "A ladle of the self-skimming type, that is, with welded or riveted sheet-iron bridge . . . is preferable for pouring, as it permits the size of the metal stream to be predetermined, prevents splashing and keeps slag at the top of the ladle from getting into the mould. If a plain ladle is used, the lip should be kept clean and free from burrs or other surface irregularities that would interfere with a smooth solid stream, and scum should be kept from entering the mould. This ladle should be held close to the pouring hole to avoid air bubbles or chilling the metal.
>
> "The metal should flow steadily and in a way to avoid splashing and pocketing of air.

A trifle more metal should be added after the mould is apparently full, in order that any impurities tending to remain after skimming will overflow. The babbitt will shrink a little in cooling, and by continuing to pour after cooling has started, shrinkage in the bottom of the mould will be at least partially compensated.

"Best results are obtained by pouring with the shells in a vertical position and directing the stream against the mandrel. Irregular shape of the mandrel may make this impossible, in which instance, the mould may be inclined for pouring at the most convenient point. Split shells poured singly at an angle should face downward. They are also sometimes placed in horizontal position on a surface plate, with convex side up over the mandrel, and the babbitt poured through holes put in the casting for that purpose.


Fig. 3—Pouring a crosshead guide using both hand and hoist-controlled ladles.

"Each liner should be poured complete at one operation, so that on large work a pot of liberal size is desirable. If the ladle is too small a second ladle should be on hand and ready as soon as the first is empty, in order that there will be no break in the babbitt.

"The kettle of molten metal and the bearing should be kept close together, as carrying a ladle of molten metal any distance is bad practice. Aside from possible danger of spilling, the ladle contents may cool enough to impair smooth flow into the mould."

Oil Grooves and Their Purpose

In order to maintain continuously effective lubrication of any sleeve type bearing, means must be available to assure distribution of oil to the entire bearing surface, and especially to that area which is subjected to maximum pressure.

Properly designed oil distributing grooves have been proven to be the most generally dependable solution of this problem where bearings of marine engines, industrial machinery or power generating or transmission equipment are involved. This is assuming, of course, that the lubricator or means of initial delivery of oil is adapted to the constructional and operating conditions which prevail.

The essential definition which might well be applied to oil grooving of bearings would be:

A depression or series of depressions connected or so located with respect to each other and the point of maximum bearing pressure as to insure not only complete and ready distribution of lubricant throughout the bearing clearance space, but also a pathway for collection and subsequent flushing out of any abrasive or other foreign matter which might gain entry to impair lubrication and lead to increase in friction and power consumption.

Oil grooves are, therefore, regarded as essential on virtually all bearing surfaces which must carry shafting or journals subjected to rotary motion, or reciprocating parts such as engine crossheads which involve sliding motion. There are, of course, certain exceptions, especially where the maximum of bearing area must be employed, or where rotational speeds may be comparatively low, even though unit pressures per square inch may perhaps be fairly high. The mandrel bearings on a textile printing machine are an example of the above.

Study of Construction Essential

There has been far too negligent an attitude on the part of many designers and builders of machinery in regard to this matter of oil grooving. Too often there is the apparent idea that if one or two oil holes are drilled in a bearing cap to provide for connection to some means of individual or collective lubrication the natural rotational effect of the journal, shaft or pin, or the sliding motion of the crosshead, for example, will draw in sufficient oil to develop the necessary film of lubrication.

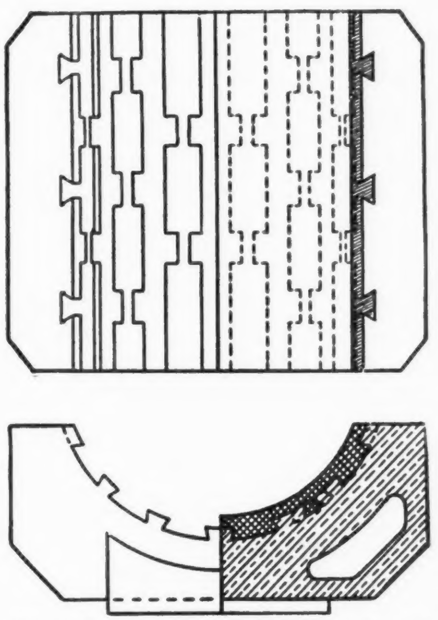
In part this will be true, and where bearing edges or the point of entry of the lubricant to the bearing are chamfered or cut away, lubrication will perhaps be effected to a sufficient

degree to at least not give cause for alarm. In fact, unless a bearing becomes so hot as to be virtually uncomfortable to touch, the extent to which it may be consuming power will be lost sight of. Actual testing in comparison with a properly grooved bearing to note the amount of power consumed, and the extent to which operating temperatures may be in excess of normal, according to the location and type of machinery involved, will be the only way to appreciate the importance of grooving as an adjunct to more efficient operation.

To, therefore, leave the location and arrangement of grooving to shop employees who have to deal with babbitting of bearings, for example, may be a dangerous procedure unless they are furnished with definite working details from their engineering department in regard to dimensions and location of such grooves.

The Actual Function of an Oil Groove

While the purpose of oil grooving of bearings has been briefly summarized at the beginning of this article, it is felt that more detailed discussion is now in order. In other words, an oil groove must:



Courtesy of The Wm. Cramp & Sons Ship and Engine Bldg. Co.

Fig. 4—Plan and sectional elevations of a bearing box, the left hand side being unfilled, the right side being filled with Parsons White Brass bearing metal. Note the ribs which effectively hold bearing metal in place. These are covered by metal to a depth of from 1/8 to 1/4 inches, according to the size of the box.

(1) Provide an initial receptacle for the receiving of oil as it passes into the bearing from the lubricator.

(2) Serve as a means whereby oil can be distributed lengthwise along the bearing, so that as the moving surface of the rotating or sliding element passes the grooves or chamfers it will take up a protective film of oil.

(3) Adequately retain oil within the bearing clearance space and prevent abnormal leakage via the bearing ends. By suitably designing a system of grooving provision can be made for virtual circulation of oil alternately from the center of the bearing to the outer ends and back again. How intricate such a layout would have to be would depend primarily upon the means of initial lubrication. Where sight feed or drip lubrication is involved, or in other words, periodic lubrication with just about the right amount of oil to maintain an adequate lubricating film, grooving will play a more important part than where flood lubrication is provided for. Examples of this latter would be the ring-oiled electric motor bearing or the pressure lubricated main bearings of an automobile engine.

Location of Oil Grooves

The essential factor in the consideration of oil grooving of virtually any bearing is simplicity. There are numerous methods in practice as shown by certain of the accompanying illustrations. Some are apparently intricate, involving quite a considerable circulation of oil, as for example Fig. 5.

In other cases there will be just a single groove cut across the bearing cap.

Where manufacturers of machinery or bearings have given study to the requirements of their specific equipment, their systems of grooving employed may be regarded as satisfactory, even though all may not be the same from the viewpoint of arrangement. The all important factor is to attain such effective lubrication that friction and power consumption will be reduced to a minimum. The means of attainment is more or less secondary, provided, of course, that available bearing area is not too markedly reduced.

In this connection it is important to mention that grooving as a general rule should be confined to those parts of the bearing which carry the least load. In a two-part stationary bearing this will mean that only the top bearing should be grooved. In a four-part bearing, the segments to consider would depend upon the direction of rotation of the journal or shaft. Normally the bottom part should be plain or ungrooved, except in cases where direction of pressure will alternate from one part of the bearing to the other according to the stroke, as for example on connecting rod bearings of a vertical reciprocating engine.

Essentially the oil must flow from a low pressure area to a zone of higher pressure. Should this latter be grooved to any extent there may be the possibility of oil being carried from the bearing, the lubricating film impaired, waste

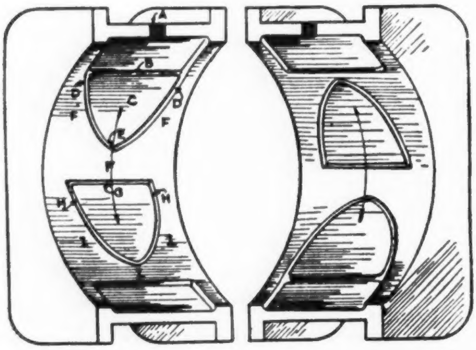


Fig. 5—Crank-pin boxes of a connecting rod showing oil grooves. Oil enters at "A"; is accumulated in the primary groove "B"; by rotation of the pin from there it is spread in both directions within the clearance space to cover surface "C." "D-D" are secondary grooves which carry oil back to the center of the bearing at "E" and at the same time maintain a film of oil over surfaces "F, F, F." From here oil works into primary groove "G" and thence to secondary grooves "H, H" where the course of development of the film is repeated as above.

increased, and the development of abnormal wear. Excessive oil leakage at the bearing ends with increase in temperature may be regarded as indications of faulty grooving adjacent to the high pressure area.

Of course, where flood lubrication is involved, the arrangement of oil grooving in a bearing will not be so important, nor so contingent upon the direction of rotation as where periodic or drip lubrication is provided for. This should not be regarded as reason for grooving a bottom bearing in, let us say, a ring or pressure oiled system, however, for lubrication would normally not be improved, and the effective bearing area in the high pressure zone would only be reduced.

On the other hand, direction of rotation must be considered more carefully in a drip lubricated bearing, for flow of oil through the oil grooves may be materially affected. Oil flow should be directed towards the center of the bearing, not towards the ends. This will all depend upon the manner of grooving, as this latter will, in turn, depend upon the direction of rotation.

Oil grooves should never be extended too close to the ends of the bearing surfaces, for in such event oil will tend to escape from the clearance space to be lost by drip or leakage. As a general rule it will be well to keep such grooves a certain distance in from the bearing ends, according to the size of the bearing and journal involved.

According to the Hoyt Metal Company of Great Britain, Ltd.:

"Grooves should be made to terminate say $\frac{1}{4}$" from either end in a bearing of $1\frac{3}{4}$" bore, or less; $\frac{3}{8}$" with a bore of 2"; and up to $\frac{1}{2}$" with bores of 3" to 6". While in large bearings they can be up to 1" or more from the ends, according to size."

PREVENTION OF OIL FILM SCRAPING

The maintenance of a suitable oil film within the clearance space of a plain or sleeve-type bearing will depend in part upon the pumping or drawing-in action which is brought about by the rotating or sliding element, according to the type of installation. Where shafts or journals are involved, it is essential to remember that effective lubrication can be most dependably attained by providing for passage of oil from the low pressure to the high pressure area. As a general rule this will mean from the upper to the lower part of the bearing.

For this reason oil holes are usually located in the top part or cap of the average bearing, when lubrication is to be maintained from an external source. In addition, by suitable grooving of the top part or low pressure area of such bearings, where practicable, delivery of adequate oil to the point of entry of the high pressure area can be more nearly obtained.

Rounding or Chamfering of Sharp Edges

But only can this be assured by eliminating the possibility of the oil film being scraped off or otherwise impaired. Sharp edges around oil holes or along grooves must, therefore, be rounded off. Furthermore, bearing edges should be chamfered or cut to a more or less beveled surface so that when the respective shells are in place an oil groove will be formed, of about the same depth and width as the grooves in the low pressure area of the bearing.

In this way flowing or wedging of oil from the grooves or oil holes into the clearance space between the rubbing surfaces can be more readily accomplished by the maintenance of a continuous Vee-shape in the oil film at such points.

It can be appreciated that where sharp edges do exist at any part of a bearing surface there will be a tendency for oil to be scraped from the smooth surface of a journal or shaft, instead of being uniformly distributed within the clearance space between the rubbing surfaces.

In fact, this rounding off of sharp edges wherever a bearing surface is broken is regarded as one of the most important details relative to the attainment of effective lubrication of plain or sleeve type bearings. And yet it is very often entirely overlooked when new bearings are being grooved. Were the bearing to be provided with a number of sharp scrapers to remove the oil from the smooth rotating sur-

face, the results could not be more serious than by leaving sharp-edged oil grooves.

Length of the Chamfer

It is important to remember that a bearing edge should never be chamfered or beveled over its entire length for this would subsequently lead to oil draining off to perhaps be wasted. If the cut is terminated a distance of from ¼" to 1" from the end of the bearing, according to the diameter of shaft to be carried (as already stated), there will be but little possibility of appreciable loss of oil.

The chamfered or beveled space, of course, will serve as more or less of an oil reservoir, just as will an oil groove, when the shaft or journal is idle. It is very important that such a condition exist in larger bearings which must carry heavy shafts, for when idle for any length of time these latter will tend to squeeze the oil film out from the bottom or high pressure part of the bearing.

As a result, virtual metal-to-metal contact will exist. On starting, unless oil is immediately delivered to such an area, friction, wear, and possible scoring may develop. If the oil grooves and chamfers are more or less filled with oil, however, the drawing-in action of the shaft as it begins to rotate will result in immediate formation of at least a partial oil film. As speed is gathered this latter will continue to improve, provided, of course, that fresh oil is delivered in the proper amount by the lubricating system.

DIMENSIONS OF GROOVES

As a general rule the dimensions of an oil groove in a sleeve-type bearing will depend upon the diameter of the shaft which is to be carried therein.

Calculation of Width

A workable formula is to multiply this diameter in inches by 0.01 and add 0.10 of an inch as more or less of a factor of safety.

For Depth of Groove

One half of the calculated width as determined above can then be assumed as the proper depth for the groove in question.

Typical Examples

It will be of interest in this regard, to work out some examples based on shafting or pins of different diameter, viz.:

No. 1

Given a crank shaft of 30 inches diameter:

$(30 \times .01) + 0.1 = 0.4$ inches—width
$0.4 \times \frac{1}{2} = 0.2$ inches—depth

In other words, the above groove would be say ⅜ of an inch wide by $\frac{3}{16}$ of an inch deep.

No. 2

Given a shaft of 12 inches diameter:

$(12 \times .01) + 0.1 = 0.22$ inches—width
$0.22 \times \frac{1}{2} = 0.11$ inches—depth

This would correspond approximately to ¼ of an inch wide by ⅛ of an inch deep.

No. 3

For a smaller bearing, say a pin of 1¾ inches diameter, it will be well to assume this latter as 2 inches as an added factor of safety. As a result:

$(2 \times .01) + 0.1 = 0.12$ inches—width
$0.12 \times \frac{1}{2} = 0.06$ inches—depth

This would result in a groove ⅛ of an inch wide by $\frac{1}{16}$ of an inch deep.

In a properly babbitted bearing the thickness of bearing metal should be ample to allow for the above calculated depths of grooves without danger of cutting through to the bearing shell. As a rule, however, it will be safest to note just how much thickness of bearing metal is actually

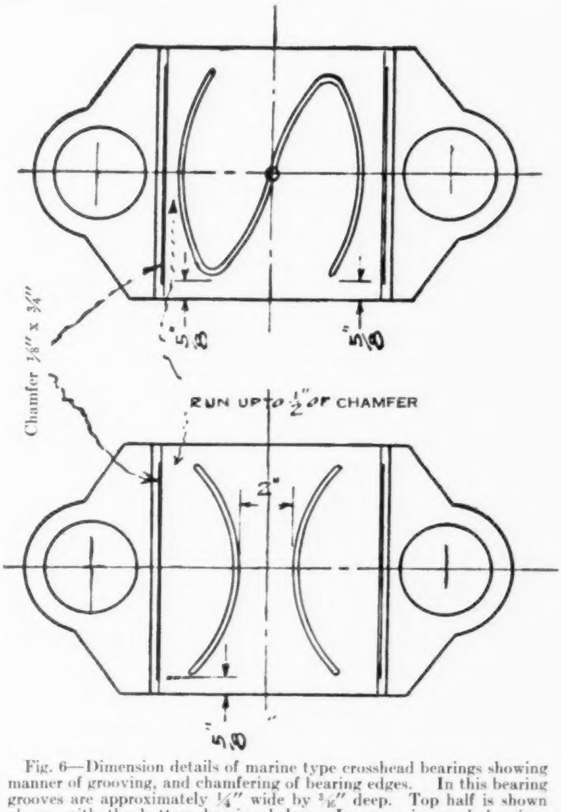


Fig. 6—Dimension details of marine type crosshead bearings showing manner of grooving, and chamfering of bearing edges. In this bearing grooves are approximately ¼" wide by $\frac{3}{16}$" deep. Top half is shown above, with the bottom bearing below. In preparing such bearings all burrs must be removed and grooves eased off at the ends.

present before grooves are cut or bearing edges chamfered or beveled.

An important point when planning a system of oil grooving and calculating the dimensions is to remember that available bearing area is

reduced by oil grooves. Of course, under normal conditions where such grooves are cut in the bearing cap or low pressure area, actual metal-to-metal contact may not be so apt to occur as over the high pressure area. And yet, pressure exists throughout the bearing; therefore, even the low pressure area should not be reduced any more than necessary by overly wide grooves, extensive chamfering or too intricate an arrangement of the former.

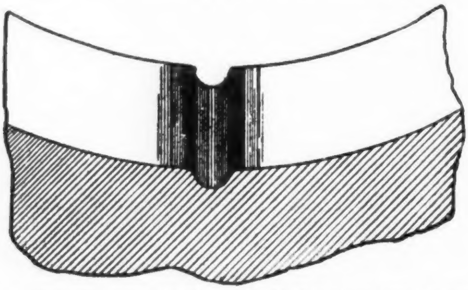


Fig. 7—The purpose of the above sketch is to show how the corners of an oil groove should be rounded off in order to prevent oil scraping. In this way flowing or wedging of oil into clearance spaces will also be facilitated.

MANNER OF CUTTING OIL GROOVES

The utmost care must be given to the cutting of oil grooves in order that they may as nearly as possible conform to the calculated dimensions, and the intended location with respect to curvature and the ends of the bearing.

It is obvious that the possibility of clogging of oil grooves will be greater should the depth be uneven, or the edges wavering. As a general rule, more or less contaminating solid foreign matter, such as dust and dirt or metallic particles, will be present in almost any oil after service for any length of time. Furthermore, if higher operating temperatures prevail, certain types of lubricants may have a tendency to break down to gummy or carbonaceous deposits. The more or less inert character of all such non-lubricating matter will render it sluggish in circulation. As a result, high spots in an oil groove may tend to act as a dam, or uneven edges as a deterrent to perfect circulation, to ultimately result in collection of deposits at such points. The natural consequence will be impaired lubrication.

Oil grooves are most frequently cut out by hand, or perhaps machined in the surface of the bearing metal. Where the former prevails, there may be more possibility of variation from the calculated dimensions, although the fineness of the work will depend, of course, upon the skill of the mechanic and the care taken in manipulation of cutting tools.

Rough surfaces must be guarded against, whatever method may be used for cutting grooves. Not only will rough spots tend to impair free circulation of oil through the grooves, but also heavier foreign matter may be more easily retained at such places. Roughness, in addition, may be indicative of loose particles of bearing metal. If adjacent to the main surface of the bearing, the occurrence of metal-to-metal contact might lead to breaking or chipping off of certain of these metallic particles, to cause contamination of the lubricant and possible scoring of the shaft or bearing surfaces if circulated with the lubricating film.

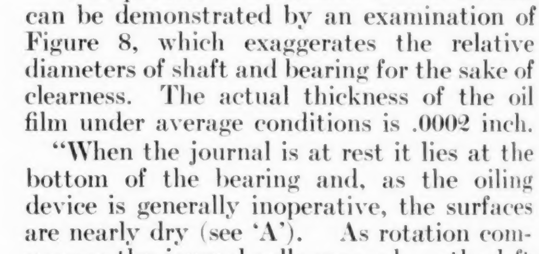
DIRECTION AND DISTRIBUTION OF PRESSURE

Pressure as developed by a rotating shaft, journal or pin is distributed through the oil film in a properly lubricated bearing, the rotating element being virtually supported by the film. The intensity of the load which must be so carried, however, will not be uniform throughout the bearing. There will be a high and a low pressure area as has already been mentioned. The point of maximum or minimum intensity will vary according to the speed of rotation involved.

Direction of pressure as indicated by the high and low pressure areas in the bearing has been mentioned in connection with location of oil grooves. This is further discussed in a most interesting manner in "Bearings and Bearing Metals" (by A. W. Cadman Mfg. Co.) viz.:

"The process of formation of the oil film can be demonstrated by an examination of Figure 8, which exaggerates the relative diameters of shaft and bearing for the sake of clearness. The actual thickness of the oil film under average conditions is .0002 inch.

"When the journal is at rest it lies at the bottom of the bearing and, as the oiling device is generally inoperative, the surfaces are nearly dry (see 'A'). As rotation commences the journal rolls upward on the left hand, or 'on' side of the bearing (see 'B'), and if the velocity is very low it will continue to rotate in this position and no oil film will be formed.



Courtesy of A. W. Cadman Mfg. Co.

Fig. 8—Showing process of formation of an oil film within a bearing clearance space. See text for further discussion.

"Immediately, however, the velocity reaches a value of even 10 feet per minute oil is drawn into the bearing by the journal and forms a wedge, as shown at 'C'. This

wedge of oil forces the shaft over to the 'off' side, raises it in the horizontal direction, and at the same time completely separates it from the bearing.

"As the velocity increases, the thickness of the oil film becomes more uniform and the center of the shaft approaches more closely to the center of the bearing.

"If the load be now increased, as the speed is kept constant, the journal tends to approach a point on the bearing about 40 degrees from the vertical, and if it be further increased the oil film will be ruptured.

"It should be noted that the pressure in the oil film is at a maximum at a point just ahead of the point of nearest approach of journal and bearing. The point of minimum pressure is just beyond the point of nearest contact and a vacuum of as much as 30 inches has been found at this point."

Means of Lubrication

The several methods of lubrication commonly adapted to the sleeve type bearing can be broadly grouped to include collective or individual means of delivery of the lubricants, as for example:

The mechanical force feed lubricator,
Circulating oiling systems,
Drip (oil) lubrication, and
Pressure or pin type greasing devices.

THE MECHANICAL FORCE FEED LUBRICATOR

In order to maintain the requisite lubricating film within the clearance spaces of many types of bearings, as on the Diesel engine, for example, oil must be delivered in measured quantities under sufficient pressure to counteract in part the operating pressures which prevail.

The mechanical force feed lubricator has been one type of equipment which has been found to be especially adapted to such service where oil is the most desirable lubricant. It can be operated under varying pressure by the machines to which it is attached. Furthermore, it can be built with a number of oil feeds, each being controlled by an individual pump in the oil reservoir.

A device of this nature is decidedly convenient and positive; equipped with separate visible feed lines to the respective bearings, it makes possible the control and maintenance of an uninterrupted supply of oil at all times, provided that periodic refilling is attended to. It is practicable also to equip such a lubricator with a return line, used oil being carried back to the reservoir for recirculation. In this way oil economy is increased.

A mechanical force feed lubricator, being practically always driven by the machine which it serves, only functions when the latter is in operation and at a proportional speed. The pumping capacity and rate of oil feed is therefore variable. By suitable adjustment of the lubricator it can be very accurately regulated to meet whatever lubricating requirements the bearings may involve.

The advantage claimed for such equipment as a one-time oiling device is that a positive pre-determined supply of clean fresh oil can be furnished to the bearings in as nearly as possible the correct amount to meet the requirements of effective lubrication. Waste can, thereby, be reduced to a minimum and general conditions of cleanliness improved. As a rule there will be very little drip from bearings so lubricated.

CIRCULATING OILING SYSTEMS

The continuous circulation of oil through bearings affords a very practical and economical way of automatically lubricating such parts with a minimum of labor or attention. As a rule a considerably greater volume of oil will be involved in a circulating system than in a mechanical force feed lubricator.

A typical circulating system will involve a suitable oil reservoir in the base of the machine, a pump for transmission of oil either to an overhead auxiliary tank, or directly to the bearings to be served, and the necessary distributing pipes to each of the latter. Each line should be fitted with a sight feed device and

Courtesy of Magnolia Metal Co.

Fig. 9—Grooving layout for ring oiled bearings of both single and double ring type. Note that one oil hole per oil ring is provided. The groove at the left end should be omitted for bracket bearings, and when the distance between the ring groove and end of the edge chamfers is less than ¾" both end grooves are omitted.

adequate means for individual adjustment of oil flow. Means will also be necessary for drainage or transmission of used oil back to the base reservoir or sump tank.

Such a system is advantageous in that it provides for sufficient settling of the oil to insure precipitation of the greater part of any foreign

matter that may have been picked up by the oil in passage through the bearings. Furthermore, the latter are practically flood lubricated, which not only means that they will normally be washed free from accumulations of foreign matter, but also cooled to a certain extent.

It is also perfectly practicable to provide for adequate pressure either by gravity or pumping, to maintain a sufficient pressure on the oil films to in part serve to resist such operating or reaction pressures as may be involved on certain of the bearings.

RING AND CHAIN OILERS

Lubrication of bearings by ring or chain oilers involves continual delivery of oil to the wearing surfaces by means of a ring or chain suspended from the shaft, and free to rotate therewith, the lower part dipping in a bath of oil which is carried in a suitable reservoir in the lower part of the bearing shell.

In order to insure effective lubrication by such mediums the reservoir must be of adequate capacity to give the oil ample opportunity to rest, thereby making possible not only the settling out of sediment and other foreign matter, but also cooling to the requisite degree. As a rule the only way in which the oil in such a system is kept at the proper temperature is by radiation of heat from the exterior surfaces of the reservoir or lower part of the bearing.

Should the latter be of apparently insufficient capacity it is possible to overcome this by fitting an auxiliary reservoir below the one in question. One way in which this can be done is to tap a short length of pipe into the lower part of the bearing, plugging the bottom end with a cap. Such a device has an added advantage in that it also acts as a dirt collector.

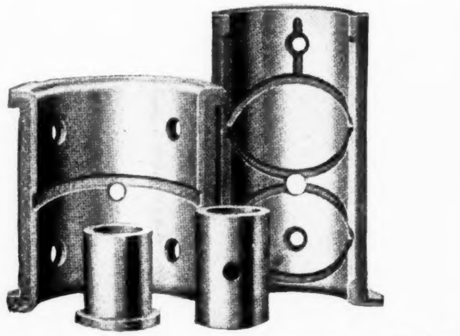
Oil which is carried to the top of a ring or chain oiled bearing must, of course, be taken care of and returned to the reservoir as rapidly as it is delivered by the ring. If this is not possible, oil will tend to accumulate in the upper part of the housing to ultimately be forced out from the ends of the bearings.

The same condition may arise if the oil is carried too high in the well, or if the ring rotates at too high a speed. This will cause a splashing and churning of the oil.

COLLAR OILERS

The principle of the collar oiler is much the same as that of the ring oiler, i.e., it involves the circulation of oil from a suitable reservoir in the base of the bearing. This is brought about by means of a collar of considerably larger diameter than the shaft, which is fastened to the latter at approximately the center of the bearing.

Such lubrication may be regarded as of more essentially the flood variety. Furthermore, it will, as a rule, be more positive than in the average ring oiler, by virtue of the fact that as soon as the shaft begins to rotate the collar being fast thereto will likewise be set in motion



Courtesy of Hoyt Metal Co.

Fig. 10—A group of bronze-backed bearings showing arrangement of oil grooves and chamfering.

to immediately carry oil to the top of the bearing. As a result, the requisite film of lubricant will be formed more rapidly on starting and maintained more effectively, especially under slower speed conditions.

An added advantage which is claimed for the collar type bearing oiler is that there is relatively no possibility of cessation of lubrication as long as the oil level in the bearing reservoir is maintained at a high enough level to insure adequate dipping of the collar. Rings, on the other hand, may tend to stick, or fail to revolve with the shaft, especially if the oil used becomes abnormally sluggish by reason of low temperature, or the entry of an excess of contaminating foreign matter.

DRIP LUBRICATION

The sight feed oil cup and wick oiler will maintain effective lubrication of many types of marine and stationary bearings. Sight feed oilers involve individual lubrication of the respective bearings as a rule, with a consequent need of individual attention, as to filling and adjustment. They are, however, advantageous, in that they normally permit of observation of the oil content from the operating floor.

The wick feed oiler, in turn, can be of either the individual or manifold type. Each is economical from a labor-saving point of view, though they may perhaps involve oil waste if improperly designed, adjusted or controlled. The manifold type can be built on very much the same lines as the wick oiler employed on certain classes of marine steam engines. Wick oiling on the whole is decidedly advantageous provided that the wicking is of proper texture and in good condition, for the wick will serve as an effective strainer to insure delivery of clean

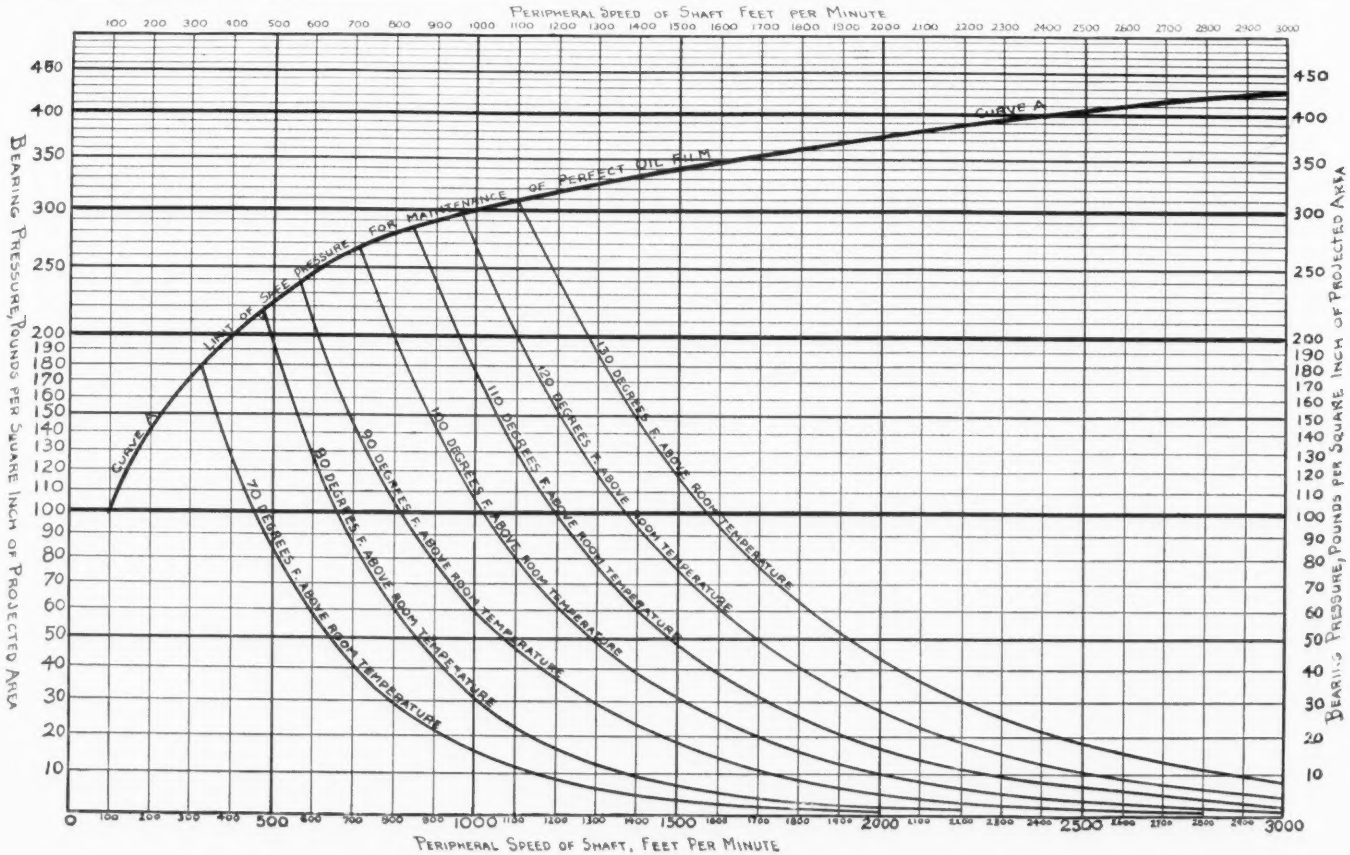


FIG. 11—CHART SHOWING RELATION OF BEARING TEMPERATURE TO SPEED AND PRESSURE.

The figures used in the preparation of this chart were obtained in tests on a ring oiled bearing of standard design. The direction of rotation was steadily in one direction under constant pressure. Changes in the direction of the load, intermittent pressure, or rapid periodic changes in pressure decrease the resulting temperatures and increase the pressure necessary to rupture the oil film. The factors by which the pressures should be multiplied in some typical classes of machinery, and under other lubricating conditions, are given below.

LUBRICATION		GAS ENGINE, STEAM ENGINE AND AIR COMPRESSOR BEARINGS		BEARINGS OF POWER PLANT MACHINERY		ROLLING MILLS	
Grease Cup	X ½	Main, total load	X 3	Horizontal Steam Turbines	X 1	Pinion Housing	X 1
Drop Oiling	X ¾	Crank-Pin, center crank	X 5	Generators and Motors	X 1	Roll Housing	X 5
Flood Oiling with Pump	X 1½	Crank-Pin, side crank	X 7	Line Shafting	X 1	Table Rolls	X 1

(Copyright 1922 by A. W. Cadman Mfg. Co.)

oil to the bearings. Periodic cleaning of wicks, of course, is advisable if the above is to be continuously maintained.

There will always be certain bearings, however, which will not require such positive means of lubrication. Usually they can be hand-oiled two or three times a day. To facilitate this the spring-cover type of oil cup is frequently installed.

Normally the same grade of oil as used in a mechanical force feed lubricator or circulating oiling system will adequately take care of such bearings as may require drip or hand oiling. Such a product should be a highly refined, straight mineral oil having a viscosity range of from 200 to 400 seconds Saybolt at 100 degrees F.

PRESSURE GREASE LUBRICATORS

Where heavier lubricants may be necessary for individual bearing lubrication, the use of grease will often be advisable. Mechanical or hand pressure grease lubricators will handle such lubricants admirably.

The pressure grease lubricator may be either of the hand or power type. For the use of the individual machine operator, the former is perhaps the most suitable device. In large installations, however, where considerable equipment may be involved, the power lubricator will often be an adjunct as a time and labor saver.

Another noteworthy piece of equipment is the constant pressure grease lubricator for use in connection with the pressure grease gun. In effect it has been designed to eliminate the necessity for frequent re-lubrication. It is, in fact, as nearly positive and automatic as practicable over the length of time that its charge of grease will last.

GREASE CUP LUBRICATION

In view of the necessity for a means of lubrication that will function relatively automatically and be capable of withstanding hard knocks, the grease cup is also extensively used on certain types of bearings. In some cases such bearings are located in dangerous and inaccessible positions, where regular oiling, or the filling of oil cups, etc., would be comparatively difficult or even impossible without complete shut-down.

Grease lubrication by means of the spring regulated compression cup or the relatively automatic pin type of cup is in such cases regarded by many engineers as an effective means of keeping such bearings operating with a minimum of care and the least amount of danger to operators.

SELECTION OF LUBRICANTS

The selection of lubricants for service in a plain or sleeve type bearing will require consideration of two broad factors, viz.:

The means of lubrication and
The operating conditions.

Means of lubrication will dictate whether oil or grease must be considered, as the provisions for application will be distinctly different. The basic details have already been discussed.

In regard to operating conditions it will be essential to consider speed, temperature and pressure. Each should, of course, be analyzed as to the possible bearing it might have upon such characteristics as viscosity, pour test, flash point and carbon residue content.

Viscosity of Oils Important

Where lubricating oils are required, unless extremes in operating temperature may be involved, the viscosity will be the most important characteristic to consider. Normally this will range from 200 to 500 seconds Saybolt at 100 degrees F. for the average type of lubricating system mentioned above. In other words, within this range an oil could be chosen which would be suited to the ring oiled bearings of an electric motor, the sight feed drip cups on a line shaft bearing, the circulating oiling system as applied to the external parts of an air compressor or steam engine, or a mechanical force feed lubricator serving a metal press.

On the other hand, intensive conditions involving low temperature, as on certain outdoor materials, handling equipment would not only require perhaps a lower viscosity oil, but also a low pour test to preclude any possibility of congealment and reduction in fluidity and circulating ability.

Where Greases Are Required

The requisite consistency of grease to use will be dependent upon the type and size of the bearings, the pressure involved, and the variety of grease cup used.

Compression cups will, in general, function best on a medium grade of cup grease.

Pin-type cups, on the other hand, involving either temperature or a certain pumping action in the attainment of flow of the grease will require products of lighter consistency.

It is relatively impossible to make specific recommendations in this regard. Operating conditions, machine design and construction, temperatures involved and the class of labor available will all require individual consideration, just as holds true where lubricating oils are concerned.

As a result the matter of grease lubrication should be discussed in detail with a capable lubricating engineer who is versed not only in the details of machine operation, but also intimately familiar with the capabilities of each of the several grades of greases available to choose from.

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